The breeding of Greater Flamingos *Phoenicopterus roseus* in the Guadalquivir marshes from 1989 to 2007

Manuel Máñez, Fernando Ibáñez, Héctor Garrido, Luis García, José L. Arroyo, José L. del Valle, Alfredo Chico and Rubén Rodríguez

Equipo de Seguimiento de Procesos Naturales, Estación Biológica de Doñana, CSIC, Apartado 1056, E-41013 Sevilla, Spain. E-mail: mmanez@ebd.csic.es

Abstract
We summarize the breeding events of Greater Flamingos in the Guadalquivir marshes, southwestern Spain, from 1989-2007. During this period the flamingos established colonies, in which they started incubation, in 8 years. There were also breeding attempts in other 3 years, in which incubation was not started. There were considerable interannual variations in breeding pairs, which ranged 120-13,200. In most years there was some management to facilitate fledging success. In spite of this, breeding success was very low, ranging 0-26.5%. The colonies suffered heavy predation by Wild Boars and gulls.

Introduction
In a previous paper (Máñez 1991) we summarized the breeding events of Greater Flamingos *Phoenicopterus roseus* in the Guadalquivir marshes until 1988, presenting data on colony sizes, laying dates and breeding success. In the present paper we summarize the breeding cases from 1989 until 2007.

Study area
Our observations were conducted at the Guadalquivir marshes in southwestern Spain. These marshes are a wetland complex (natural marshes, ricefields, fish farms, saltworks) in which water levels mainly depend on rainfall. In a typical year, the marshes flood in autumn/winter and dry out in June/July (see Valverde 1958).

Material and methods
Once the settlement of adults was observed at breeding sites, we paid regular visits to those sites to estimate laying dates. Laying date was considered as that in which the first egg was observed, or by backdating from hatching dates. We estimated colony sizes from an airplane or from land. Once breeding had finished and there were no adults around the colonies, we estimated the number of nests and counted the number of both unhatched and depredated eggs, as well as the number of dead chicks. The number of chicks alive was also estimated, or counted directly when chicks were reared in captivity (see below). The difference between the number of nesting pairs and fledging chicks served to estimate breeding success. Meteorological data were obtained from the station at Palacio de Doñana, and are referred to the period September-April.

Results

After the breeding season of 1988 (Máñez 1991), Greater Flamingos did not attempt breeding again until 1996, likely because of a dry period, in which yearly rainfall was always < 480 mm, except 1989-1990 when rainfall was 953 mm.

The main breeding parameters of the breeding attempts during 1996-2007 are summarized in

Table 1. From 1996 onwards, Greater Flamingos no longer bred at the site used during 1977-1988 (Veta de las Vaquiruelas in Doñana National Park, Máñez 1991). Breeding success in the Guadalquivir marshes during 1996-2007 was very low (0-26.5%, Table 1).

In 1996 the colony was established in late May at Vetones del Burro (Marisma de Hinojos, Doñana National Park), and deserted in late June because of heavy nest predation by Wild Boars Sus scrofa. In 1997 the colony site was occupied in late April. Only 600 adults remained after a heavy hailstorm on 30th May, some of which have their belly feathers tinged with eggs' yolk, suggesting that many birds deserted the colony because of hail. On that date we counted 98 chicks. The large number of deserted eggs attracted Black Kites *Milvus migrans* and Lesser Black-backed Gulls *Larus fuscus*, as well as Wild Boars. On 19th June there were no adults nor

chicks at the colony site, and only 19 were found in nearby sites. Such chicks were captured and reared in captivity, being released when able of flying.

Table 1. Location of breeding sites of Greater Flamingos, breeding parameters, and rainfall (September-April) in the marshes of the Guadalquivir, SW Spain, during 1996-2007. All sites, except Veta la Palma (a fishfarm) and the saltworks of Sanlúcar de Barrameda, are in Doñana National Park. (Colony size= number of nests or number of pairs).

Year	Site	Colony size	Nesting pairs	Chicks hatched	Fledging	Rainfall* (mm)
1996	Vetones del Burro	1250	≥ 205	0	0	897.0
1997	Vetones del Burro	700	≥ 220	98	19	
	Veta la Palma	30	0	0	0	782.8
1998	Vetones del Burro	1000	≤ 1000	155	138	672.71
2000	Madre Marismas	7	0	0	0	
	Veta la Palma	80	0	0	0	399.1
	Salinas de Sanlúcar	70	0	0	0	
2001	Veta Castellana	30-40	0	0	0	
	Vetones del Burro	2539	≥ 1781	956	281-311	651.3
2002	Vetones del Burro	3.020	≤ 3020	0	0	560.2
2003	Vetones del Burro	15226	≥ 5186	2285	963	
	Veta del Hierro	1000	≥ 120	0	0	549.1
2004	Vetones del Burro and other 6 sites	13507	≥ 13187	5331	3500	710.0
2005	Veta la Palma	80	0	0	0	167.0
2006	Veta Reguera	50	0	0	0	434.6
2007	Veta Reguera	500	≤ 500	90-95	52	
	Veta Ansares	1200	1200	0	0	633.2
	Veta del Hierro	300	≤ 300	0	0	

*Referred to September-April

The breeding site was occupied in 1998 in late April by about 1000 pairs. On 19th June, when water levels were very low, all chicks were captured and reared in captivity until they were able of flying, being then released.

Water levels in the marshes were very low in 1999 (rainfall = 240 mm), and there was no breeding, though there were two breeding attempts (nests constructed). One of them was in a fishfarm (Veta la Palma), where the flamingos had also attempted breeding in 1997 and 1998. The other attempted case of breeding in 1999 was at the saltworks of Sanlúcar de Barrameda.

Water levels in the marshes in 2000 were also very low, and in spite of that, Greater Flamingos attempted breeding, laying four eggs that were abandoned before incubation. There were also two additional breeding attempts, but the sites were abandoned before laying.

In mid-April 2001 Greater Flamingos attempted breeding at Veta Castellana in Doñana National Park, but the site was soon entered by Wild Boars, and the flamingos deserted. Almost simultaneously, the flamingos started laying at the Vetones del Burro. On 19th June we captured all chicks (956), which were transported by vehicles to a flooded fenced area (4 ha) located 8.2 km north of the breeding site. In the afternoon of the same day in which the chicks were moved to the flooded area, we observed adults feeding their chicks. However, in this site there was an episode of intoxication by cyanobacteria (Alonso-Adicoberry *et al*. 2002), and only about 30% of chicks survived (the exact number is difficult to estimate, because these site was used by fledgings dispersing from the Fuente de Piedra colony).

In 2002 the Vetones del Burro were occupied in mid-April, but the site was deserted on 25th April, after Wild Boars entered the colony. There were also two failed breeding attempts, one of them in Veta la Palma fishfarm, and another in Sanlúcar de Barrameda saltworks.

In 2003 the flamingos occupied first the Vetones del Burro, and there was also one late breeding attempt in Veta del Hierro (Marisma de Hinojos, Doñana National Park). On 15th June there were no adults incubating, and all chicks were in a compact crèche. Because the marshes started to dry out, a corridor (450 m) was made by mowing emergent vegetation, connecting the breeding site with areas in which water levels were deeper. On 9th July the chicks were guided to these zones of deeper water by men on horseback. However, most chicks were not able to fly before these zones dry out, so that on 25th July all remaining 1209 chicks were captured and transported by vehicles to the same flooded fenced area to where chicks were moved in 2001. We estimate that about 80 % of chicks survived.

Water levels in 2004 were high and breeding success was the highest for the studied period. In this year, human intervention was minimal. The flamingos settle first in the Vetones del Burro in late March, but during April other three colonies were established, located at Veta del Hierro, Veta Reguera and Veta de los Ánsares. All these colonies produced chicks. Furthermore, in May, the flamingos settled at Veta Quemada, Veta Tres Puntas, and Pacil de Veta la Arena, where some chicks hatched in the first two sites. On 12th July the chicks were guided by men on horseback to flooded areas through a system of corridors in which emergent had been mowed.

2005 was the driest year of the studied period, and the flamingos did not attempt breeding in Doñana National Park, though in mid June we observed 80 nests in Veta la Palma fishfarm, where no eggs were laid.

About 6000 flamingos settled in early April 2006 in Veta Reguera. We counted 50 nests on 11th April, but the site was deserted in late April. No laying was detected.

Finally, in 2007 the flamingos settled in three sites located at Veta de los Ánsares, Veta del Hierro and Veta Reguera, though chicks hatched only in the last one. Most nests at these sites were preyed upon by Wild Boars and Yellow-legged Gull *Larus michahellis*. We recorded a few cases of chick predation by Black Kites and Red Kite *Milvus milvus*.

Discussion

Despite that flamingos bred in rainy years, when water levels were higher, some management was necessary because wetlands in the marshes usually dried out before the chicks could fly (see also Valverde 1960, Rodríguez 1983, Máñez 1991). However during years in which water levels were very high, such as 1990, the flamingos did not attempt breeding, likely because the nesting sites were flooded. In years of low water levels, when rainfall during September-April was < 480 mm, there were some breeding attempts, mostly in saltworks or fishfarms, but the flamingos did not laid eggs.

There was no correlation between rainfall, indicative of water levels, and colony sizes or fledging successes in the Guadalquivir marshes (see Table 1). Colony size in these marshes may be related to breeding conditions in Fuente de Piedra lake, which seems to be preferred as breeding sites by Greater Flamingos (Rendón *et al.* 2001). In spite of management actions, breeding success in the Guadalquivir marshes was very low in most years, as predators usually entered colony sites and this caused the desertion of nesting sites by adult flamingos.

Acknowledgements

Carlos Urdiales, from the Administration of Doñana National Park, coordinated the rearing in captivity of flamingo chicks. The wardens of the National Park, personnel from Reserva Biológica de Doñana and Reserva Natural Laguna de Fuente de Piedra, and many volunteers participated in the capture and ringing of chicks. Juan A. Amat and Olga Ceballos commented on a previous version.

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om 1997 to 2007, in eight ringing operations, 3,135 chicks were banded. As many as 7,278 resightings, corresponding to 1,837 individuals, have been made on 2,717 chicks banded up to 2006 (Table 2).

Table 2. Numbers of banded chicks, individual bands read and total sightings

Year	Locality	Banded	Individuals resighted	Total resightings
1997	Molentargius	404	315	1,482
1999	Saline Macchiareddu	200	134	738
2000	Molentargius	383	169	835
2003	Saline Macchiareddu	312	250	1,068
2004	Saline Macchiareddu	499	353	1,402
2005	Saline Macchiareddu	426	302	939
2006	Saline Macchiareddu	493	314	814
Total		**2,717**	**1,837**	**7,278**

Most chicks leave the breeding site just after fledging. Apart from the 1,076 Sardinian re-sightings (data strongly influenced by re-sightings sessions made in the nursery soon after banding), most re-sightings came from France, Tunisia, Spain, the Adriatic, Algeria and the Tyrrhenian coast of Italy (Figure 1). Probably, the main dispersion areas of young Sardinian flamingos is North Africa, as suggested by the relatively high number of re-sightings from Tunisia and Algeria, where the reading effort is presumably lower than in France, Spain and Italy.

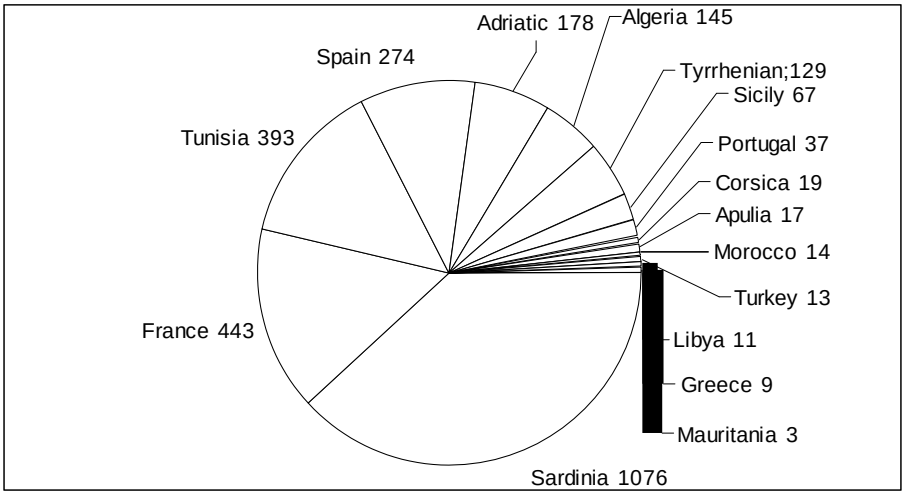

Figure 1. Number of individuals banded in Sardinia up to 2006, and re-sighted in different countries or regions

Discussion

Conservation of the Sardinian breeding population depends mainly on the management plans of the two breeding sites: the active salt-pans of Saline di Macchiareddu and the disused salt-pans of Stagno di Molentargius, which are presently a Regional Park, the management of which is actually under discussions.

However, band re-sightings during the breeding period suggest that survival of the breeding population also strongly depends on the management of many other Sardinian wetlands within a radius of 100 km from Cagliari that the birds use for feeding. The availability of abundant food

resources and the low incidence of limiting factors help explain the high productivity recorded to-date at the Sardinian colonies. An increase of re-sighting effort at the feeding wetlands during the breeding period is one of the monitoring priorities of flamingo project in Sardinia.

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The Flamingo Project in mainland Italy: an update of the situation at the end of 2007

Giuseppe Albanese[1], Giovanni Arveda[2], Nicola Baccetti[3], Paolo Dall'Antonia[4], Federico Morelli[5]

[1] Gargano National Park, I-71037 Monte Sant'Angelo FG, Italy
[2] via dello Zuccherificio, I-44022 Comacchio FE
[3] ISPRA (ex-INFS), Ozzano Emilia BO. E-mail: nicola.baccetti@infs.it
[4] Centro Ornitologico Toscano, CP470, I-57100 Livorno LI
[5] Istituto di Scienze Morfologiche, Università di Urbino, I-61029 Urbino PU

Abstract
This paper provides a summary of the colony sizes, breeding success and ringing totals at the two Greater Flamingo *Phoenicopterus roseus* breeding colonies of mainland Italy (Margherita di Savoia and Comacchio), from their initial colonisation through 2007. Both colonies are located along the Adriatic coast. They exhibited marked growth only during the first few years following their initial settlement. Chicks have been ringed every year only at the Comacchio colony. The distribution of resightings spans the entire Mediterranean, although in NW Africa, there have been fewer resightings of Italian-ringed birds than of birds ringed at more western colonies. Ring monitoring at the Adriatic colonies has revealed that the origin of the breeding birds at both sites is similar. Locally ringed birds are now well represented among Comacchio breeders.

Introduction
In the past decade, Greater Flamingos have regularly bred on the Adriatic coast of the Italian peninsula: at Margherita di Savoia in the south (since 1996, Figure 1) and at Comacchio in the north (since 2000, Figure 2). Both colonies are in salinas, although industrial salt extraction ceased at Comacchio in 1985, and water levels are now kept relatively constant year-round. The Comacchio saltpans, c. 400 ha, occupy just a small corner of a larger natural wetland (Valli di Comacchio, 12,500 ha) that is connected to the sea by canals and characterised by a relatively high tidal regime for Mediterranean standards. At Margherita di Savoia, the salina is nearly 10 times larger and entirely covers what, in ancient times, was a coastal lake. Salt production still goes on and has recently been privatised. As there is no specific management of the flamingo breeding sites in either location, breeding success is quite variable. In this report, we provide data on breeding colony sizes, breeding success and ringing totals at both sites, since their initial colonisation to 2007. We also discuss some preliminary results obtained by ring resightings at these sites.

Materials and methods
The two sites were monitored with a very different intensity, temporal coverage at Margherita di Savoia being usually less complete (especially in recent years). Colony size was usually determined by counting nest mounds in all colony sectors where there had been incubating adults. Breeding success was estimated at Comacchio by counting all trapped and escaped/released chicks during the ringing operation. At Margherita di Savoia, breeding success was estimated by censusing the nursery as late in the season as possible, before any juveniles fledged. The Comacchio ringing operations were performed by teams of up to 100 participants, usually in early July, following the La Tour du Valat methodology.

Figure 1. One of the three colonies that were simultaneously present at Margherita di Savoia in June 2005 (photo G. Albanese). This peripheral dyke (originally 6 km long, now fragmented into several sections) has hosted all the successful colonies recorded since the year 2000, (*i.e.* since erosion has made all the central dykes unsuitable).

Figure 2. The Comacchio colony in May 2008 (photo G. Arveda). Here flamingos have always bred in the same part of the salina, on man-modified islands within a large semi-natural pan ('Valle Lamenterio') once used in the pre-evaporation stage.

Results and discussion

Colony size, breeding success and ringing totals

Figures 3 and 4 offer an overview of the colony size, number of fledged juveniles (as an indication of breeding success), and ringing totals in the two colonies up to the year 2007. The phenomenon of autumn breeding, observed in the early Margherita years (cf Johnson & Cézilly 2007), was never recorded more recently. Breeding success is usually quite low especially at Margherita, where water levels are regulated according to industrial criteria, with sudden floods and similar problems. A proportion of chicks usually greater than 50% was ringed every year at Comacchio only (N ringed = 2322 from 2000-2007).

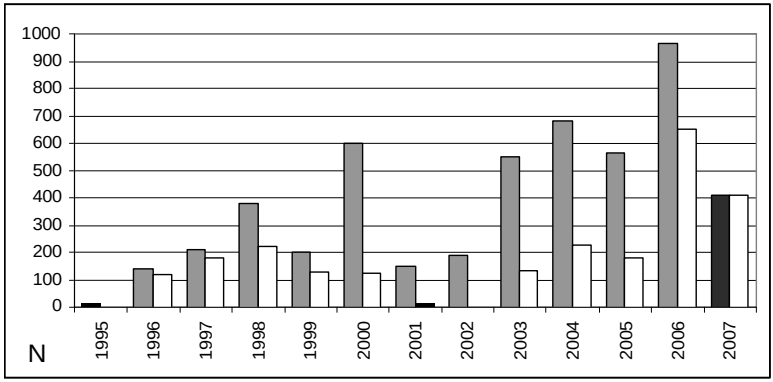

Figure 3. Colony size data from Margherita di Savoia. Grey bars: number of breeding pairs (from empty nest counts); white bars: number of fledged chicks. Nests were not counted in 2007 (black bar: minimum estimate, equalling number of chicks).

Ring monitoring in Italy and elsewhere

The start of Italian ring sightings has been impressive, with nearly all the birds of the first cohort being resighted within one year after fledging (Baccetti and Dall'Antonia 2002). However, it was not an ephemeral performance. There were 991 resightings of the 2005 cohort from banding to their second year of life (July 2007), corresponding to the observation of 248 individuals out of 255 ringed. Overall, through 2007, the blue Comacchio rings had been resighted 19,954 times on 2,122 individual birds.

Figure 4 shows the localities where at least one Comacchio-ringed bird has been recorded. The southwestern part of the range (*e.g.* Morocco) turns out to be unusually poor of dots, being probably seldom visited in comparison to what appears from dispersal maps of birds of a more western origin (*e.g.* see Tab. 9 in Johnson and Cézilly 2007). In the souteast, by comparison, there is possibly a gap in coverage. A recent (post-2007, thus not shown) bird shot in Syria and two observations in eastern Libya, however, represent a significant extension in this sector. Within Italy, but outside the breeding colonies, many wetlands have now a local team of regular ring-readers and a sort of 'competition' among them is organized every year on a fixed date, in order to further spread this activity among bird-watchers and improve the site coverage.

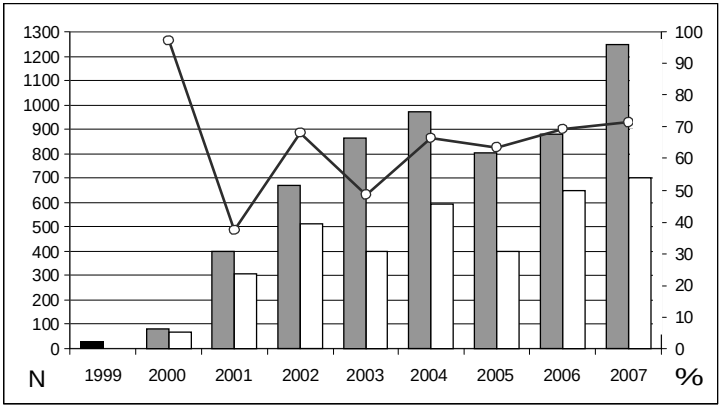

Figure 4. Colony size data and ringing performances at Comacchio. Grey bars: number of breeding pairs (from empty nest counts); white bars: number of fledged chicks; line (referred to the second y-axis): proportion of chicks that were caught and ringed.

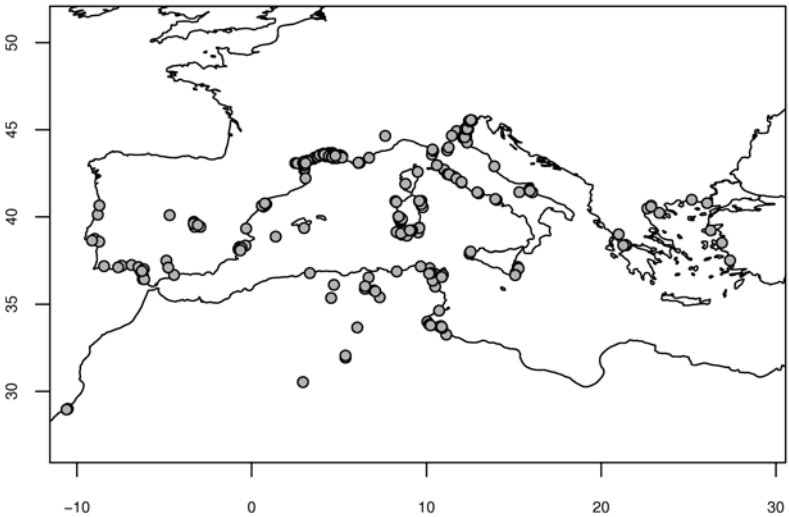

Figure 5. Sites of observations of all the Comacchio-ringed flamingos, based on nearly 20,000 ring readings

Ring monitoring at the two colonies

Ring-monitoring is conducted every year at the Comacchio colony, whereas monitoring at Margherita di Savoia occurs quite irregularly (no ring readings of breeding birds in 1997, 2000, 2001, 2005, 2006; max. 60 rings read in 2003). Nevertheless, the origins of the ringed breeders appears to be remarkably similar in the two colonies (Figure 6), except that at Comacchio, birds of local origin are obviously over-represented when compared to the Comacchio origin at Margherita, whereas at Margherita no category exists for locally ringed birds.

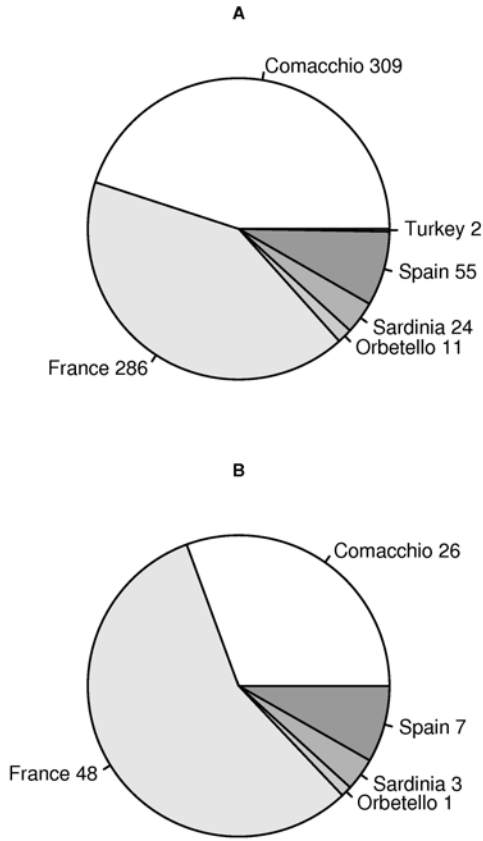

Figure 6. The natal origin of marked birds recorded breeding at Comacchio (A) and Margherita di Savoia (B). Periods of reference are: for A, all years 2000-2007 (min: 22 individuals in 2000, max: 267 individuals in 2007); for B, eight years from 1995 to 2007 (blank years listed in text). Andalucia and the Ebro delta were lumped in the 'Spain' category. Small sample size in B (85 inds./year vs. 687 in A) did not allow recording the rarest origin (Turkey). At Comacchio (A), single Turkish birds were recorded as breeders in 2004 and 2007, Comacchio-hatched birds were recorded every year since 2002, and all the other origin categories were represented every year.

In the Comacchio colony, Comacchio-hatched birds were recorded every year from 2002, when they first appeared as apparent recruits (Figure 7). After the age of 2-3 years, no cohorts seem to be represented by increasing numbers of birds. Some cohorts (*e.g.* 2002) are over-represented compared to the others, due to an originally higher number of ringed birds. However, this does not bias a comparison made along the rows of Figure 7 (*i.e.* looking at the importance in time of each particular year of birth), because in these graphs, the same individuals were counted anew for each year of monitoring, and there is probably a strong effect of site fidelity. A hypothesis that we may be able to test statistically, once the sexually mature cohorts are more numerous is: A small colony, such as the Comacchio colony, which shows no real signs of increase, but provides very constant habitat conditions, may be a settling option for a given number of local birds just when

they are at the age of their first breeding attempts. The rest of the birds of the cohort would then start queuing at any of the 'big' colonies (Fuente de Piedra, Fangassier, Macchiareddu), or attempt colonizing new sites. The group of birds that succeeded in settling at Comacchio would appear again one year later with a similar individual composition (due to philopatry), and thus with the same number of birds. This pattern would repeat in time, leaving perhaps progressively less space for the younger cohorts, but each one of them being constantly represented in time. It would be interesting to carry on monitoring this and other 'small' colonies, beside the big ones, in order to confirm this hypothesis.

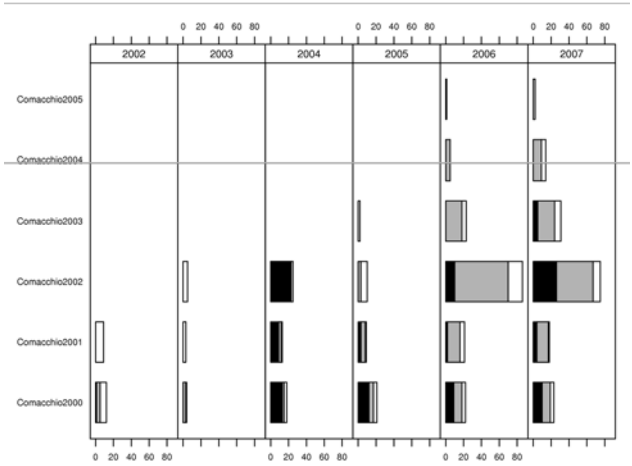

Figure 7. Presence in the Comacchio colony of locally-marked breeding birds in every year (columns) since they first appeared as apparent recruits in 2002: white, "at the colony" (juvenile birds excluded); grey, probably breeding (dirty plumage, paired, displaying near colony); black, confirmed breeders. Number of birds in the x-axes.

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Analysis of the mass of raw data on Greater Flamingos *Phoenicopterus roseus* on their wintering grounds, particularly in North Africa

Mike Smart [1], Hichem Azafzaf [2] & Habib Dlensi[3]

[1] *143 Cheltenham Road, Gloucester GL 2 0JH, UK. smartmike@btinternet.com*
[2] *11 Rue Abou El Alla El Maari 2080 Ariana , Tunisia. E-mail:azafzaf@gnet.tn*
[3] *B.P.: 86, 3018 Sfax, Tunisie. DLENSI.H@topnet.tn*

Abstract
Over the last forty years a great deal of data has been collected on the Greater Flamingo *Phoenicopterus roseus* in Tunisia, including winter and summer counts, and the resightings of >10,000 ringed birds. Sadly, these data have never been systematically analysed. This paper presents an outline of the situation in Tunisia, emphasising the need for analysis of the data in order to fill what we consider as a major gap in our understanding of the Greater Flamingo population dynamics and migratory strategy.

Introduction
A great deal of data has been collected on flamingos in Tunisia. This includes counts, with information on numbers at a variety of sites going back over forty years. For some years there are near-complete censuses of all major sites, mainly in the winter period but also in summer. In addition, a vast number of readings of Darvic rings (c. 10,000 readings) have been made since the ringing programme in the Camargue began in 1977. In recent years, there have been readings of rings from the Ebro and Andalusian colonies in Spain, from Sardinia, Orbetello and Comacchio in Italy, from Algeria, and from Turkey.

Sadly, these data have never been collected or systematically analysed, so the information and views presented here are based on field experience and impressions over many years, rather than on systematic analysis. In general, detailed studies of flamingos have in the past concentrated on the breeding grounds, where the major research stations and the biggest concentrations of scientists are found. However, since the flamingos spend more than half the year away from the breeding colonies, this period of their life also needs to be fully analysed and understood. In this paper we present only an outline of the situation in Tunisia, but we suspect that the same is true of Algeria and Morocco.

The Importance of Tunisia for Greater Flamingo
Tunisia is generally considered to be important as a wintering ground for Greater Flamingos. In fact, the country is also important at other times of the birds' life-cycle, for breeding and summering, and for the generally overlooked function as a 'kindergarten' for immature flamingos.

The Tunisian Government designated 19 new Ramsar sites on 7 November 2007, including several major flamingo sites such as Korba, Sejoumi, Kelbia, Thyna Saltpans, Kneiss Islands, three sites round Djerba and Bahiret el Bibane. Basic site conservation measures are in place.

Importance for breeding flamingos
Traditionally, breeding occurs in Tunisia only occasionally, after unusually wet winters, and normally in large natural saline basins in central and southern Tunisia. Major historical breeding events were in 1970, with a massive breeding colony at Chott Jerid/Fejaj, in 1974 at Sidi el Hani with 10,000 pairs, and in 1991 at Sidi Mansour with 4,000 pairs (Figure 1; Johnson and Cézilly 2007). There has been no major breeding colony in Tunisia since 1991. We are due for a wet winter in southern Tunisia fairly soon, as suggested by previous gap durations among the breeding episodes. This event, when it finally comes, should meet a favourable situation in terms of teams of wardens, observers and ringers.

In addition to traditional breeding at huge colonies in southern Tunisia, occasional breeding attempts are made by small numbers of birds, probably only just sexually mature. In Thyna saltpans, small breeding attempts are recorded almost every year, with finally 17 young raised in

2007, probably the first time in recent years that young have actually fledged (Azafzaf *et al.* 2007). Breeding has also occurred at least once in the last 20 years, probably unsuccessfully, at Ariana, Sejoumi, Lake of Tunis and Ichkeul. It would be possible (and not too difficult?) to create a man-made breeding site in Tunisia like those in southern Europe (*e.g.* at Thyna saltpans), but the question remains if we want to encourage such measures.

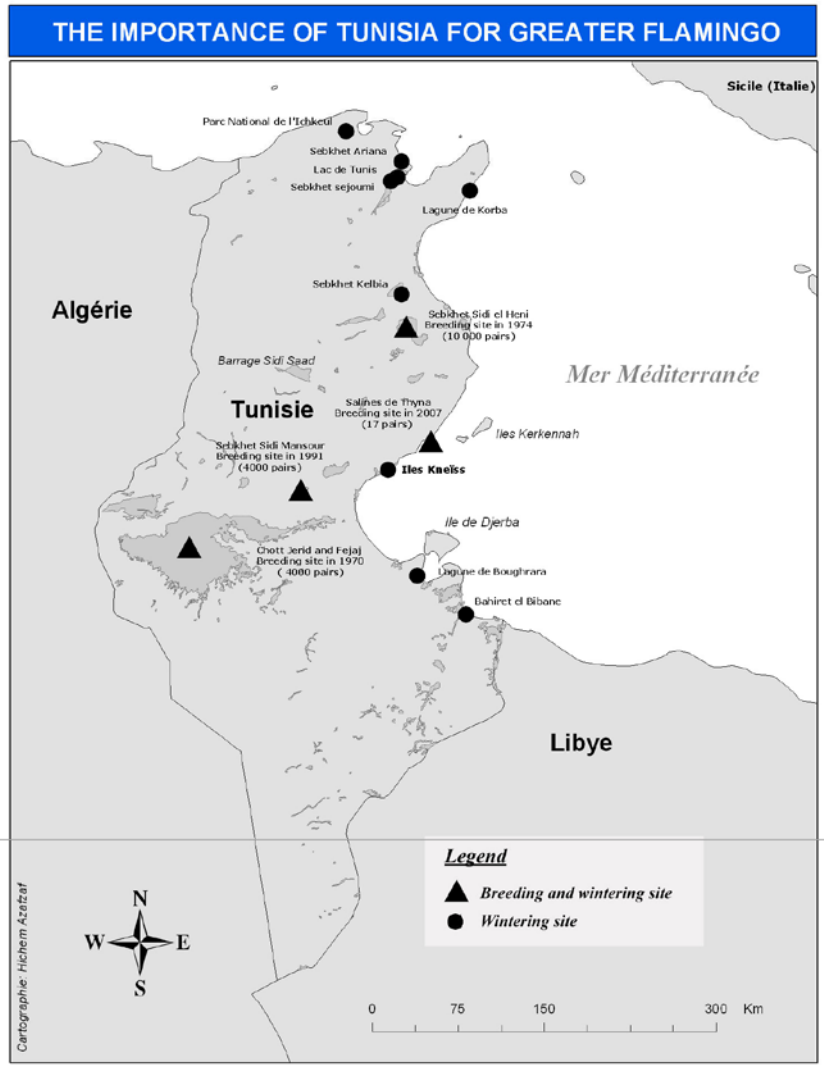

Figure 1. The main breeding and wintering sites of Greater flamingos in Tunisia. Source: Johnson and Cezilly 2007.

Importance for summering flamingos

Not all sexually mature adults return to breeding colonies in Europe. Many which winter in the vast saline depressions of southern Tunisia are obliged to move north in summer because southern sites dry out. Are these birds waiting for a wet year when they can breed in the south? Or, are the adults seen in Tunisia in summer failed breeders returning early from the colonies? Do some birds never return to European colonies? Ring resightings indicate that some adults (especially Spanish birds) arrive in Tunisia as juveniles and seem to stay for a very long time, without ever returning to their natal area.

Some summering sites (*e.g.* Sejoumi) have much higher proportions of adult birds while others (*e.g.* Korba) attract more 2-3 year old birds (Figure 1). It is possible that there are different summering areas for different age cohorts. Other sites where water is not too saline (*e.g.* Ichkeul National Park – IBA n° 002 since the restoration of fresh water conditions in winter 2002-03) attract large numbers of birds in July-August, probably coinciding with hatching of invertebrates. How important is this for flamingo survival? The analysis of ring readings would help provide answers to the above questions.

Importance for wintering flamingos

Large numbers of Greater Flamingos winter in Tunisia, with probably up to 40,000 individuals coming (as shown from ring readings) from all breeding colonies of the Mediterranean metapopulation. The importance of wintering grounds for annual survival remains poorly understood. Wintering adults seem more likely to winter in Tunisia if they spend their first three years there. The arrival of juveniles, in turn, occurs in different proportions every year, also according to climatic conditions (*e.g.* wind direction; Green *et al.* (1989)) at the moment of leaving Europe. Some wintering sites seem to be occupied preferentially by adults, others (*e.g.* probably Bou Ghrara - IBA N° 038 - in the far south; Figure 1) by very young birds (cf also Vand der Have *et al.* 1997). If young birds are forced to use suboptimal sites, what is the effect on survival?

Importance as a kindergarten

There is clearly huge pressure on recently fledged birds from European colonies to seek food resources elsewhere. They arrive in Tunisia in large numbers very early (some by early August, only three weeks after fledging and ringing). Once arrived, most stay in Tunisia for at least three years before returning to colonies. Tunisia thus plays a vital role as a "kindergarten" for all European colonies.

This kindergarten period is clearly crucial in a flamingo's life history, and raises a number of unanswered questions. What are mortality rates in these first three years? What factors cause mortality? Are there particular sites where immatures congregate in the first three years? What causes them to return to the colonies? How many flamingos which have spent their kindergarten years in Tunisia return to winter in Tunisia, and how many go to other wintering areas?

The need for analysis

A large number of juvenile flamingos spend the whole of their first three years (at least!) in Tunisia. Many breeding adults spend more than half the year in Tunisia with some adults spending all their life in Tunisia, apparently waiting for a wet year. Tunisian wetlands are therefore essential for the survival of a large fraction of the meta-population. Analysis is therefore needed to define and understand the importance of these sites.

A network of flamingo observers has now developed in Tunisia. Its members need to receive feedback on the importance of their observations, to provide encouragement for future work. They also need guidance on which topics are of greatest interest in future.

The task ahead for analysis

The census data should be collected and analysed, to improve definition of how many birds occur in different seasons, to pinpoint the key sites for different age groups, and to identify any changes over the period of the data. The ring readings should be analysed in much finer detail, among other things to define common patterns of movement, and preference of different age groups for different sites.

It is assumed that the colour-ringing centres are willing to make all ring readings available to bone fide analysts. It would seem most sensible for the analysis to be carried out in Tunisia, partly

because scientists attached to the breeding colonies are already over-stretched, and partly because it would be desirable to train Tunisian experts. The AAO (Association des Amis des Oiseaux – the national BirdLife partner) and the Tunisian universities are the obvious bodies to carry out this work. Indeed many graduate and postgraduate theses are already being prepared on ornithological topics and they would benefit from advice and contacts with existing flamingo specialists.

In the long run, it would be desirable (in Tunisia as in many other Mediterranean countries) to establish national ornithological centres, staffed by a small number of professionals who would coordinate the fieldwork of voluntary observers.

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Monitoring of Greater Flamingo colonies: some proposals for measuring and interpreting results

Miguel Ángel Rendón[1], Araceli Garrido[2], Juan A. Amat[1], Manuel Rendón-Martos[2]

[1] Department of Wetland Ecology, Estación Biológica de Doñana, C.S.I.C. Av. Américo Vespucio s/n, E-41092 Sevilla, Spain. E-mail: *ma_rendon@ebd.csic.es*
[2] R.N. Laguna de Fuente de Piedra, Consejería de Medio Ambiente, Junta de Andalucía, Apartado 1, E-29520 Fuente de Piedra, Spain.

Abstract
Monitoring programs for the Greater Flamingo *Phoenicopterus roseus* have been implemented in several colonies of the Mediterranean basin and northwest Africa. Methodologies used to obtain estimates of population sizes, breeding success, and demographic parameters may substantially differ among localities. It is important to attain a consensus on methodology in order to make the results obtained from different colonies comparable. In this paper we review the methods used to estimate the size of the breeding colonies, the behaviour of banded individuals, and the body condition of adults and chicks, based on the experience obtained from studies conducted in the Fuente de Piedra colony (southern Spain). The main results of this paper are: (1) the size of Greater Flamingo breeding colonies was systematically underestimated when reoccupations were not taken into account, (2) ring readings must be accurately applied, and field data must be filtered to obtain unbiased demographic parameters, and (3) accurate estimates of body condition for both adults and chicks should consider recent feeding and provisioning patterns.

Introduction
Population monitoring programs involve regular recording of parameters in order to understand the processes that operate at the individual and population level, thereby providing valuable information for scientific and management purposes (Yoccoz *et al*. 2001). The Mediterranean population of Greater Flamingos has been studied since the 1960s (Johnson 1997), and since then a number of monitoring programs have been implemented in the Mediterranean and northwest Africa (Johnson and Cézilly 2007). Information gathered from these programs has enabled inferences to be made relative to the processes acting upon the metapopulation dynamics of the Greater Flamingo across its Mediterranean distribution range (Nager *et al*. 1996, Barbraud *et al*. 2003, Amat *et al*. 2005).

Among the variables monitored in Greater Flamingo breeding colonies are counts (Rendón-Martos 1996, Béchet and Johnson 2008), measures of productivity and breeding success (Cézilly *et al*. 1995, Rendón *et al*. 2001), indices of chick body condition (Cézilly *et al*. 1995, Amat *et al*. 2007, Béchet and Johnson 2008), biochemical and haematological parameters (Amat *et al*. 2007, in press), and demographic estimates through mark-recapture studies (Lebreton *et al*. 1992, Barbraud *et al* 2003). Other variables are difficult to obtain in this species, despite their potential importance (*e.g*. body condition of adults).

Several approaches that differ in accuracy and meaning have been applied to obtain estimates of the variables monitored in breeding colonies. Counts are made from the air (Béchet and Johnson 2008) or ground (Rendón-Martos 1996), depending on the colonies, and peak counts or continuous censuses have been applied to estimate breeding population size. However, the accuracy of counts varies greatly if the objective of the study is to evaluate wintering or breeding populations (Green and Hirons 1988, Johnson and Cézilly 2007). Estimates of breeding success and body condition of chicks have been obtained with standard methodologies, as applied to other bird species. Breeding success is calculated as the percentage of pairs that fledged young (Cézilly *et al.* 1995, Rendón-Martos 1996), so accurate estimates of number of breeding pairs which actually laid an egg is essential to assess this parameter. In relation to the body condition of chicks, two methods have been applied: the slopes (Cézilly *et al*. 1995) and the residuals (Barbraud *et al*. 2003, Amat *et al*. 2007, Béchet and Johnson 2008) of the tarsus length-body mass relationship. Beside the suitability of either method, systematic deviance from the true chick mass may occur because the chicks store meals in the crop, but rarely this aspect is taken into account (but see Amat *et al*. 2007).

With regard to the resighting of marked individuals, codes have been established to categorize the status of individuals during the breeding season (Johnson 1983, Rendón-Martos 1996). However, lack of skill or rigor in the allocation of the codes (or perhaps just different interpretations of the code meanings) can cause loss of valuable information on the breeding status of birds, which prevents reliable monitoring of reproductive events in the colony. Such methodological differences can make it difficult to compare results from monitoring programs conducted in different colonies. Therefore, it seems necessary to attain a consensus on the methods used to record breeding parameters in Greater Flamingo colonies, as well as on their interpretations.

The aim of this paper is to discuss several aspects of the monitoring in Greater Flamingo breeding colonies, based on the experience obtained at Fuente de Piedra Lake (hereafter referred to as FP). The monitoring of the colony in this Natural Reserve began in 1984 (Rendón-Martos 1996), and since then the Consejería de Medio Ambiente (Department of Environment) of the Junta de Andalucía (Regional Government) has developed intensive surveys in this breeding colony. When possible, we will compare the differences between the parameters obtained using the methodologies applied in FP with regard to those applied in other breeding colonies. We are aware that several methodologies applied in FP would not be feasible elsewhere, because of the unique characteristics of each colony. However, despite this fact, we stress the need for obtaining comparable parameters from different monitoring programs in order to understand the mechanisms that operate in the Mediterranean metapopulation of Greater Flamingos.

Breeding pairs estimates

The number of simultaneously breeding subcolonies at FP varied each year from zero to eleven depending on the number of breeding pairs that attempted to settle, and the availability of suitable nesting sites (Rendón-Martos 1996). The substrates for the settlement of the colonies were usually artificial dikes of former salt pans (Figure 1), but in wetter years these dikes flooded and the colonies are established on natural islets.

The main colonies established between 1984-2006 at FP, both on artificial dikes and natural islets, were gridded into quadrats of 10x10 m (Figure 1), and the central dike was marked with canes every 10 m.

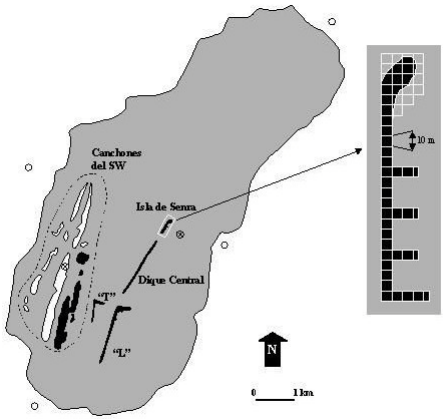

Figure 1. Location of natural islets and artificial dykes occupied (in black) by nesting colonies of Greater Flamingos during 1984-2007 in Fuente de Piedra Lake. The distribution of quadrats on the main nesting site (Isla de Senra) is shown. (: locations of hides; ○: census points).

Counts of incubating birds by quadrat were made using a spotting scope, both from hides located about 250 m from the nesting sites and from elevated locations around the lake (Figure 1). In the colonies where there were no reference marks, location of settlements were recorded by

visual references on the ground or by covering the colonies using a fixed field of vision with a spotting scope. Individuals counted incubating in each sector were recorded as breeders. In the absence of disturbances by predators, if a quadrat was occupied for more than 45 days, it was considered that there was reoccupation of the sector, and newly counted individuals were added as new breeders.

In addition to the counts, the colonies were mapped at least once a week, and the surface occupied and the behaviour of breeders per quadrat was recorded. When the breeding season finished, nests built in every quadrat were also counted (Rendón *et al*. 2001). The numbers of nests were equated to breeding pairs. The maps of nests occupied and the distribution of incubating birds throughout the breeding season were compared. As with the counts, it was considered that a quadrat was reoccupied if settlements lasted more than 45 days. Results of this double surveying were averaged in order to obtain annually the number of breeding pairs.

In order to compare the estimates of the number of breeding pairs at FP colony that we obtained by census methods (hereafter "breeding pairs") with those obtained through counts when peak numbers are incubating, we used both the mean counts of birds on the colony in the month of highest density and the number of nests recorded once the breeding season finished. Data correspond to the 1984-2006 period, but for 1996, 1999, 2000, and 2004, nest numbers were not available.

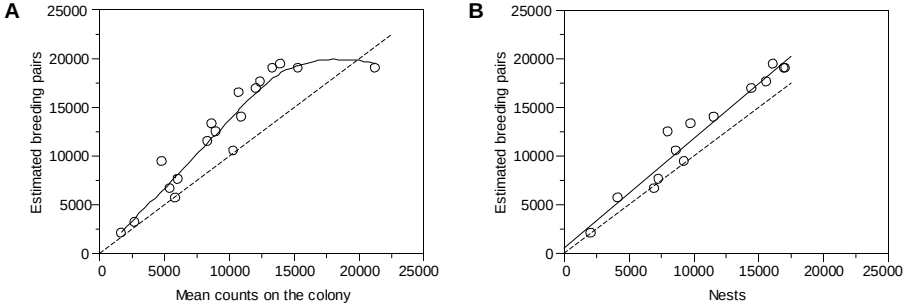

Figure 2. Scatter plot of annual breeding pairs *vs*. mean counts of adults in the month with peak number of birds (A), and the number of nests (B) at the FP colony during 1984-2006. Solid lines represent (A) smoothed curve (smoothing spline λ=3e+10, r^2=0.93) and (B) linear model (r^2=0.95, p<0.001). Dashed lines are the lines of equality.

Comparisons between breeding pairs and both peak counts and nest numbers showed that the two last methods underestimated the breeding population (Figure 2). The mean difference between breeding pairs and peak counts was 2,852 ±567 (t_{14}=5.03, p<0.001), which represents an average error of 22% ±3. Absolute differences between peak counts and breeding pairs increased when peak counts were higher (slope of the linear range: 1.35, C.I. 95%: 1.12-1.57). Furthermore, as peak counts increased, the number of breeding pairs tended to become asymptotic. This relationship suggests that there were a number of transient individuals potentially prospecting for nest sites at the colony, but that they did not attempt breeding. In this case, peak counts overestimated the number of breeding pairs when the carrying capacity of the colony was reached. With regard to the relationship between nest counts and breeding pairs, the mean difference was smaller and less variable than those obtained from peak counts (1,844 ±377, t_{13}=-4.89, p<0.001; average error of 16% ± 4). Differences with breeding pairs also increased with the number of nests but to a lesser extent (slope: 1.26, C.I. 95%: 0.96-1.29), and no asymptotic relationship was observed.

The estimation methods of breeding pairs not only affected the colony size estimates, but also the relationship of breeding pairs with environmental variables. Precipitation is known to affect Greater Flamingo breeding colonies (Cézilly *et al*. 1995, Rendón-Martos 1996, Béchet and Johnson 2008). Rendón-Martos (1996) stated that accumulated precipitation between October-April in Doñana marshes affected the breeding population of flamingos at FP colony during 1984-

1994. These marshes are located about 150 km west of FP, and are the main foraging grounds of adult Greater Flamingos during the chick rearing period (Rendón-Martos 1996, Amat *et al.* 2005). Using the same data set, we compared the fit of a logarithmic model using breeding pairs, nest numbers, and peak census as dependent variables and accumulated precipitation as an explicative factor (Figure 3). The best fit was obtained from the estimated breeding pairs (r^2=0.79), followed by nest number (r^2=0.52), both models being significant at the 0.05 level. On the contrary, annual variation of peak counts was not significantly related to the accumulated precipitation (p=0.083).

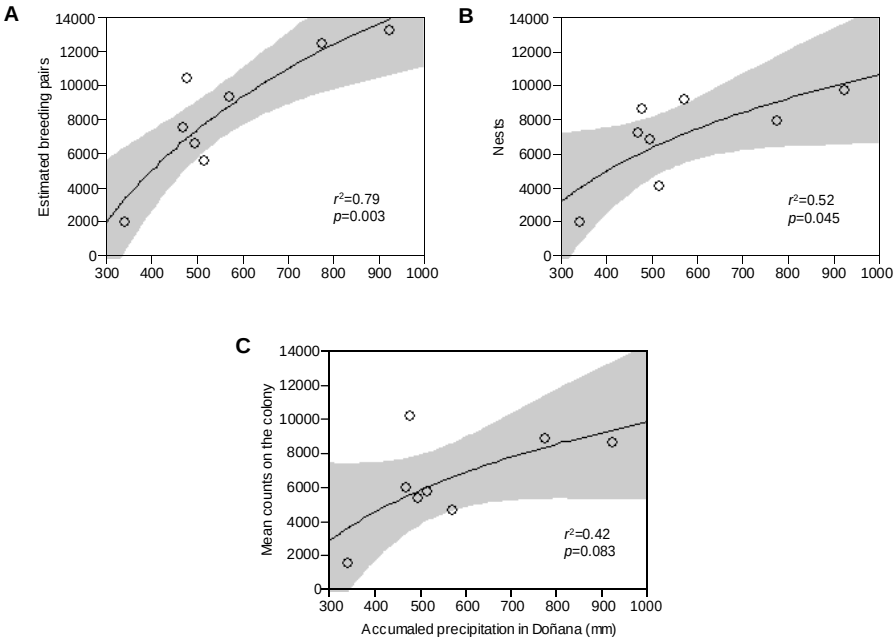

Figure 3. Logarithmic relationship between accumulated precipitation (October-April) in Doñana and (A) breeding pairs, (B) nest numbers, and (C) peak counts of birds on the colony in FP during 1984-1994. Shaded areas are 95% confidence fits. Coefficient of determination and significance of the models are shown.

Ring readings

The methodology applied to assign behaviour codes to individuals in breeding colonies was developed by Alan Johnson in the Camargue (Johnson 1983). Status codes assigned to individuals standardize a wide range of behaviours, from presence in the lake (*e.g.*, code 00, healthy bird) to specific breeding activities (Appendix I). The number of ring readings and the behaviours recorded in the colonies of the Mediterranean region and northwest Africa differed among localities. As an example, Figure 4 shows the frequency distribution of ring readings in 2006. It is evident that the number of records of banded birds did not match with the breeding populations at different areas due to differences in sampling effort. On the other hand, resightings focused on different behaviours (*e.g.*, birds near the colony *vs*. specific breeding activities) and breeding phases (*e.g.*, incubation *vs*. chick attendance) in each colony. Thus, while for most localities, resighting records were concerned with individuals close to the colony or crèche (code 20), in Algeria and Comacchio records were registered more frequently for individuals classified as probable breeder (code 29), and in Delta del Ebro the records show a high proportion of adults attending chicks outside the colony (code 45). This lack of homogeneity in resightings may

prevent a representative sample of marked individuals across the breeding season that enables the comparison of demographic rates among colonies.

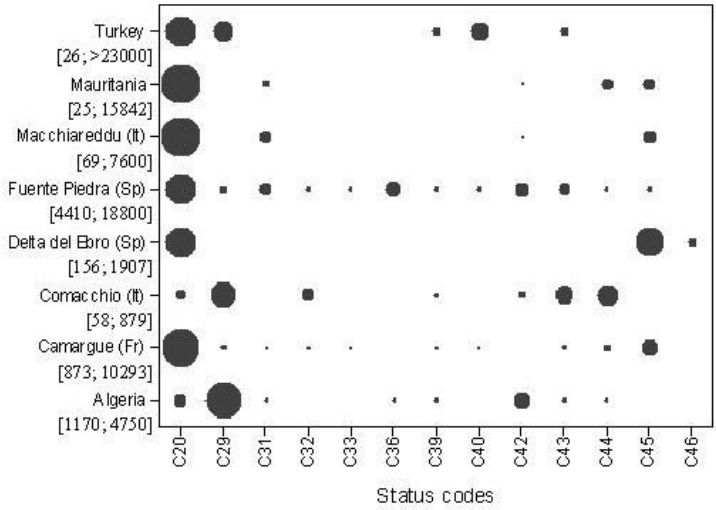

Figure 4. Proportion of status codes (code ≥20) recorded from ring readings in different colonies of Greater Flamingos in the western Mediterranean and northwest Africa during 2006. Dot sizes are related to the fraction of records in each colony. When colony name was specified, country abbreviation was provided in parentheses (Fr: France, It: Italy, Sp: Spain). Sample sizes of ring readings and breeding pairs are in brackets. Data obtained from SIAM (Suivi Individuel d'Animaux, C. Germain, La Tour du Valat) and Béchet (2006).

Accuracy in allocating status codes is essential to consider individuals as breeders. Individuals on a breeding colony can be classified as probable breeders (code 29). However, allocation of this status without confirming reproductive behaviour can lead to mistakes. Even when an individual can be located on a nest, this behaviour is not a guarantee of incubation, because individuals could be transients. In order to prevent this uncertainty, an adult observed as a probable breeder must only be considered as an accepted breeder if it stays in the same nest ≥3 days (code 39), and the following observations of the same bird on the nest will be classified as a known breeder (code 40), unless an egg or chick are visible (codes 42-63). The generalized use of these criteria will guarantee a reasonable degree of reliability on the breeding status of individuals. However, this categorization entails the filtering of the ring readings before their inclusion in any common database (*i.e.*, change from code 29 to 39, and 39 to 40 when appropriate), otherwise codes may lose their meaning. For instance, if an individual recorded more than three times as code 29 is not considered as code 39, any user of the data can interpret that bird as having changed its nest site.

The codes that identify behaviours other than those related to reproduction (*e.g.*, codes 21, 31, 32, 33, 36), are less represented and are more likely to be recorded when sampling effort increases (Figure 4). Despite that the probability of sighting marked individuals displaying, some of these behaviours may be limited, and the aim of the monitoring in most of the breeding sites is to confirm and identify the presence of breeders, we encourage checking for the occurrence of these other behaviours because it will enable the study of processes acting on successive phases of the breeding period (*i.e.* display, pairing, copulation, and nest building).

Finally, we advise against the use of uninformative codes (*e.g.* code 22, which corresponds to a single individual observed alone before colony settlement). Codes must be mutually exclusive and stated according to the presence of an identifiable characteristic and not to the absence of

attributes (Legendre and Legendre 1998). The characteristic defining code 22 is the absence of a pair, which actually is unknown from such observation because there is no definitive evidence that an individual without pairing behaviour is not paired. Therefore, code 22 should be deleted, and individuals exhibiting that behaviour included into the code 00 (behaviour unknown).

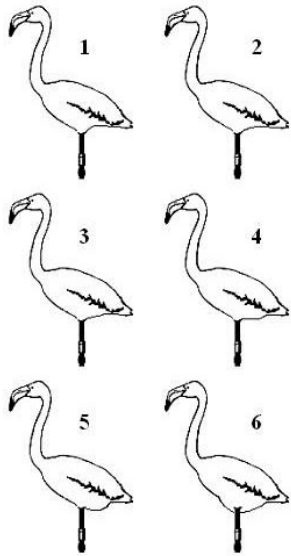

Figure 5. Categories of API used for adult Greater Flamingos (1: concave, 2: slightly concave, 3: plain, 4: slightly convex, 5: convex, and 6: hanging). Modified from C. Barbraud and A. R. Johnson (pers.com.)

Body condition of adults

Adult body condition is a relevant parameter because it is a determinant of migration (Drent *et al.* 2003) and breeding decisions in birds (Weimerskirch *et al.* 2001). Body condition has been associated with stored fat mass, which is the main form of stored energy in birds (Griminger 1986). One of the most accurate techniques for measuring body condition involves the capture of individuals. However, in the case of Greater Flamingos, the capture of adults may be very difficult and stressing for the birds. Furthermore, recaptures of the same individual are highly unlikely.

As an alternative to the capture of birds, semi-quantitative indexes of roundness of the abdominal region (abdominal profile index, API) have been applied to estimate the stored energy in birds (Owen 1981). A positive relationship has been established between API and body mass (Moriguchi *et al.* 2006), and it has been used to measure body condition in several species (*e.g.* Wiersma and Piersma 1995, Ferns and Lang 2003, Madsen and Klaassen 2006).

API categories for Greater Flamingos were adapted by Barbraud and Johnson (pers. com.) from those of other species, and were described in six ordinal scores, from concave (1) to hanging profiles (6) (Figure 5). As far as we know, there are no published studies that corroborate the relationship between body condition and API in flamingos, or whether structural size must be taken into account in order to make API a useful body condition index (Moriguchi *et al.* 2006). Preliminary results of breeding flamingos at FP indicated that there were temporal variations in API for both males and females (Figure 6). From the seasonal variation of API emerged a decreasing pattern of abdominal roundness. API was higher in incubating birds and decreased during incubation and while adults attended chicks. However, this pattern differed between sexes in such a way that while, for males, the decreasing in API occurred progressively throughout the breeding season, females only decreased their API from incubation to the chick-at-nest period, and maintained similar values during incubation and chick rearing.

In order to use API as a useful body condition index in field studies, it is necessary to account for several factors affecting short-term changes in this index. The variation of API in 19 individuals observed by the same observer at FP indicated that birds with API scores 2-3 in the morning changed significantly to score 4 in the evening and *vice versa* (Figure 7). This observation is in accord with other field observations that showed that individuals increased API during feeding and drinking. Furthermore, if feeding behaviour affects short-term changes of API, feeding conditions or proximate factors (*e.g.* water level) must also be accounted for. Regarding the example from Figure 6, a significant negative temporal trend in API was detected for both males and females, suggesting that the summer dry-out of the lake affected the abdominal roundness. Though other interpretations of this result are possible, with these examples we want to stress that the inclusion of the behaviour of birds and feeding conditions in statistical models can account for confounding factors that affect short-term variation of API.

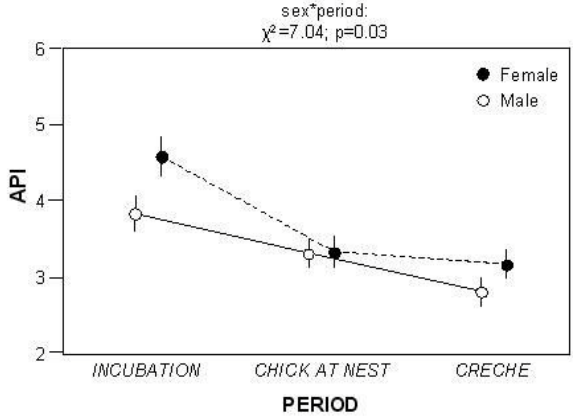

Figure 6. Mean values (±SE) of API for males and females over the breeding season at FP colony in 2001. Interaction sex*period was significant in a generalized linear model, which also included as effects: sex, period, time, sex*time, and period*time.

Body condition of chicks

The body condition of chicks has long-term consequences on individual fitness (Cam *et al.* 2003). Measuring body condition index (BCI) involves determining energy reserves, after accounting for structural body size. The more common method to estimate BCI is using the residual from a regression model of mass on body size, although there is disagreement on which statistical methods must be applied (Green 2001, Schulte-Hostedde *et al.* 2005). BCI has been estimated for Greater Flamingo chicks from the linear relationship between log mass and log tarsus, using both annual slopes (Cézilly *at al.* 1995), and individual residuals (Barbraub *et al.* 2003, Amat *et al.* 2007, Béchet & Johnson 2008). Furthermore, blood parameters also have been useful in documenting changes in body condition (Amat *et al.* 2007). Nevertheless, because a flamingo feeds its chick with secretions (Johnson and Cézilly 2007) that the chick stores in its crop for more than 13 hours (M. A. Rendón *et al.*, unpubl.), the accuracy of BCI could be biased. The mean daily weight of meals ingested by four-seven week old chicks raised in captivity was *c.* 340 g. (Batty *et al.* 2006), and for free-living individuals the mean mass of food received by chicks was estimated as 336 g (Amat *et al.* 2007). This extra mass can jeopardize the accuracy of BCI estimates and make them unreliable because of short-term provisioning patterns.

Since 1998, crop profile indices (CPI) have been recorded during the ringing of chicks at FP, assigning each crop size to one of four pre-established categories, from concave (0) to turgid crop (3) (Figure 8). In order to show the effects of CPI on the estimates of BCI, linear models were applied for three selected years with different rainfall patterns in the Doñana marshes (dry, normal and wet), which conditioned low, mean and high breeding populations at the FP colony (table 1) (see above). The first model included total tarsus length, year, and their interaction as explicative

factors of chick body mass. In addition, the second model included the CPI scores and CPI*year interaction to test both the effects of food stored on the body mass, and if such effect was consistent across years. Finally, a third model integrated all the factors included in the second model with the identity of the observers estimating the crop sizes as a random effect, because observers changed between surveys.

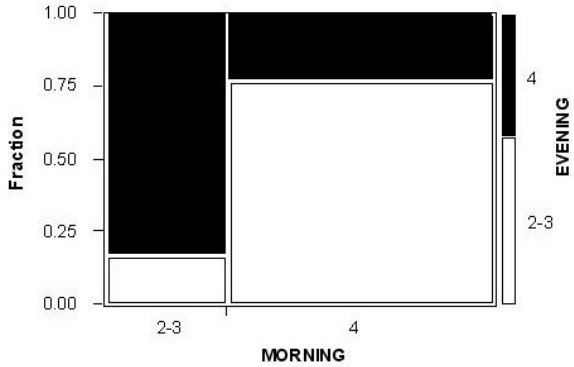

Figure 7. Values of abdominal profile index (API) for 19 individuals recorded by the same observer in the morning and the evening in FP. API scores changed across the day (Fisher's exact test: n=19; p<0.05).

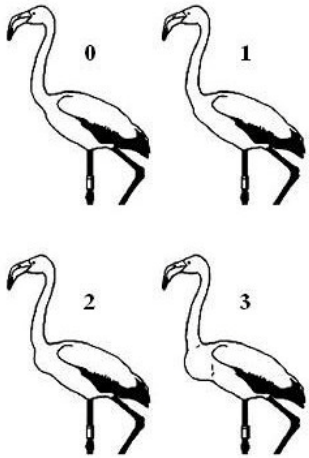

Figure 8. Categories to which the crop profile of Greater Flamingo chicks was allocated (0: concave, 1: slightly convex, 2: convex, and 3: turgid)

The results of the first model showed that the tarsus*year interaction on the chick body mass was significant, and the explanatory power of the model was high (R^2=0.68). According to Béchet and Johnson (2007), the body condition of chicks was lower in years with the higher colony density. The second model showed a significant effect of CPI on body mass (R^2=0.72). Thus, it was evident that body condition was systematically overestimated when CPI was ignored (Figure 9). Furthermore, tarsus-mass slopes also varied, depending on whether CPI was or was not included in the models. In the wettest year, when the body mass was lower, the tarsus-mass slope was steeper in the model that did not include CPI (Figure 9, line C), and no differences

between slopes were appreciable in the driest year, when mean body mass was higher (Figure 9, line A).

Table 1. Regression models of factors affecting the mass (log-transformed) of chicks banded at FP colony in three years, with both different hydrological conditions in Doñana marshes and breeding populations. The first model included log tarsus, year as a categorical variable. and their interaction. The second model also included the individual crop profile index (CPI) as a categorical variable, and the interaction year*CPI. The third model was a mixed model including the variables applied in the second model as fixed effects and observer identity as a random effect. Components of the variance of the mixed model are specified for both observer and error. Sample size comprised 2,685 chicks.

Model 1: R^2=0.68

Source	*d.f.*	*F*	*p*
log tarsus	1	3136.346	<0.001
Year	2	786.110	<0.001
log tarsus*year	2	33.273	<0.001

Model 2: R^2=0.72

Source	*d.f.*	*F*	*p*
log tarsus	1	3410.796	<0.001
Year	2	732.6909	<0.001
CPI	3	129.3904	<0.001
log tarsus*year	2	27.2353	<0.001
CPI*year	6	2.1466	0.045

Model 3: R^2=0.78

Source	*d.f.*	*F*	*p*
log tarsus	1	4938.754	<0.001
Year	2	605.879	<0.001
log tarsus*year	2	47.937	<0.001
CPI	3	156.396	<0.001
CPI*year	6	1.285	0.260

Random effect	*Variance component*	*S.E.*	*% of total*
Observer	0.0059	0.0032	37.5
Residual	0.0098	0.0003	62.5
Total	0.0157		100

Therefore, the inclusion of CPI in the models determined differences both in the annual mean body mass estimates and in the tarsus-mass slopes, due to the absolute proportion of chicks fed each year and the relative distribution of chicks fed with regard to their tarsus length (*i.e.* age), respectively. The second model also showed a significant effect of CPI*year interaction on body mass, indicating that a same category of CPI indicated different values of mass in different years. When observer identity was included as a random effect, the regression model improved the variation explained (R^2=0.78), and approximately 38% of the unexplained variance was accounted for by observer identity. Mixed model also resulted in a non-significant effect of CPI*year interaction, suggesting that the inclusion of observer identity in the model accounted for variations due to differences in the abilities to perceive CPI categories.

Food stored by chicks not only affected the estimates of body condition obtained from body mass-tarsus length relationship, but also affects the blood parameters. Thus, Amat *et al.* (2007) showed that recently fed chicks, as indicated by CPI, had higher levels of plasma metabolites such as proteins, uric acid, tryglicerids, and glucose, which are frequently used in other species to asses the body condition of individuals (Figure 10). This result stresses the importance of accounting for crop content when relating body mass variations to blood parameters. In the case of Greater Flamingo, once the effect of crop content on blood parameters and body mass was controlled for, Amat *et al*. (2007) determined that cholesterol levels were related to body condition of chicks. Annual variation of cholesterol levels and CPI were associated (mean cholesterol concentration *vs*. percentage of CPI 3: r_S=-1, n=4, p=0.083, significance determined by permutation), which suggested that frequencies of crop sizes also could be a useful index of feeding frequency (Figure 10).

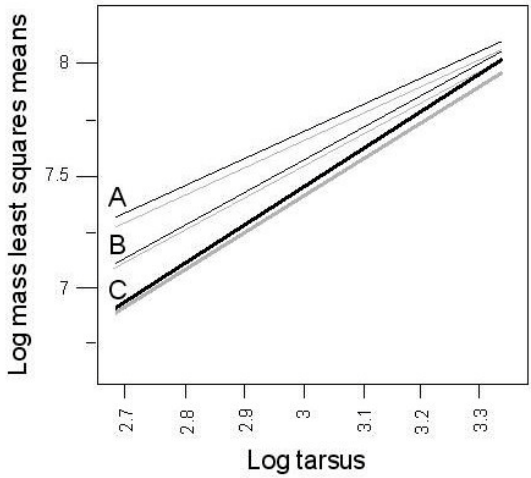

Figure 9. Relationship between chick mass and tarsus length at Fuente de Piedra during dry (A), normal (B), and wet (C) years in Doñana marshes. Black lines correspond to a model including log tarsus, year, and log tarsus*year as independent variables. Grey lines are the predictions for individuals with empty crop corresponding to a model that also included crop categories as a predictor.

Conclusions

We have attempted to outline some aspects of the methodology used in the monitoring of Greater Flamingo colonies that we next summarize.

1- Regarding estimates of numbers of breeding pairs, reoccupations of nests must be taken into account or otherwise population could be underestimated. When continuous monitoring is not feasible, nest counts seem to provide more reliable annual indices of breeding populations than peak counts.

2- Ring reading effort must be increased in several areas (*i.e*. Turkey and Mauritania) in order to obtain accurate estimates of the demographic parameters of the Greater Flamingo metapopulation. Ring readings should be gathered during the whole breeding season. Late observation could prevent the detection of breeding individuals leaving the colony in early breeding stages. Status codes must be rigorously applied and field data accurately filtered before they are added into databases to prevent mistakes. Furthermore, sampling effort devoted in each area should be reported in order to perform accurate capture-recapture models.

3- Body condition index for adults can be easily recorded using API scores. Nevertheless, the analysis of this index must take into account that recent feeding and drinking, as well as food availability can modify API estimations in the short-term.
4- Crop profile is a useful index of the food stored by chicks, and its effects must be taken into account when body condition indexes are estimated from tarsus-mass relationships or blood parameters. Furthermore, annual records of CPI seemed to be related to the feeding frequencies of chicks.
5- Because both API and BCI are ordinal measurements rated subjectively by different observers, models fitted must use observer identity as a random effect.

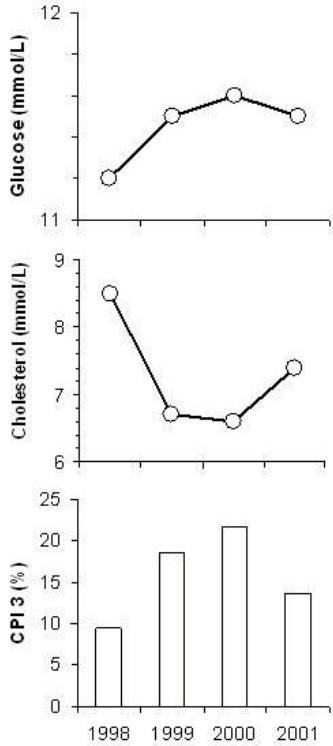

Figure 10. Annual variations of the percentage of chicks with turgid crops (CPI 3), and blood concentrations of glucose and cholesterol in chicks banded at Fuente de Piedra colony. Mean values of blood parameters were taken from Amat *et al*. (2007)

Acknowledgements
The members of the Reserva Natural Laguna de Fuente de Piedra, particularly J. M. Ramírez, conducted counts in the colony for most years analyzed. Data on colony monitoring were obtained within the "Programa de Anillamiento de Flamencos of the Consejería de Medio Ambiente (Junta de Andalucía)". Data of ring readings in the Mediterranean and northwest Africa were obtained from SIAM software (Suivi Individuel d'Animaux Marqués, Christophe Germain, La Tour du Valat). We thank Christophe Barbraud and Alan Johnson for permission to use the figure of abdominal profile index. We also thank Arnaud Béchet and Nicola Baccetti for reviewing the manuscript and providing helpful suggestions. During manuscript preparation we were funded by a grant from Ministerio de Educación y Ciencia, Spain, with EU-ERDF support (project CGL2005-01136/BOS).

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Appendix I. Status codes allocated to resightings of Greater Flamingos banded with Darvic rings. Modified from SIAM system (Suivi Individuel d'Animaux Marqués, C. Germain, La Tour du Valat).

Behaviour		Code	Definition
Unspecific		00	Pairing/breeding status and behaviour unknown
		01	Only ring found
		02	Dead
		03	Injured or ill
		04	Injured or ill, released
		05	Injured or ill, kept in captivity
		06	Trapped and released
		07	Trapped, kept in captivity
		08	Released
		99	Darvic ring lost, metal ring read
Breeding	Possible breeder	20	Close to breeding flamingos or to the crèche
		21	Brief bout of display
		22	Single (observed alone before colony settlement)
	Probable breeder	29	Believed breeding
		31	Intensive display
		32	Paired
		33	Copulates
		34	Copulates with ringed bird
		36	Bird having built a nest
		37	Paired with ringed bird
	Accepted as a breeder	39	Accepted breeding (≥3 days on the same nest - egg/chick not visible)
		40	Known breeders (but egg/chick not visible)
		42	Incubating, egg seen
		43	Attending chick on nest
		44	Feeds/attends check in creche still on island
		45	Feeds/attends check in creche having left island (ring not visible)
		46	Feeds ringed chick
		47	Feeds chick not ringed
Chick provisioning		60	Chick fed by ringed adult
		61	Chick fed by unringed adult male
		62	Chick fed by unringed adult female
		63	Chick fed by unringed adult

A common database for the ring resightings of the Greater flamingo *Phoenicopterus roseus* in the Mediterranean

Christophe Germain and Arnaud Béchet

La Tour du Valat, Le Sambuc, 13200 Arles, France. E-mail : germain@tourduvalat.org

Introduction

At the heart of the study of the population dynamics of the Greater Flamingo in the Mediterranean and West Africa is a ring resighting methodology. In order to manage the data gathered by this approach a good database program must have several properties. It must be fast, user-friendly and allow for the rapid producing the birds' life histories for volunteers who sent their observations. The metapopulation project launched in 2002 ambitioned to rely on the integration the data from several banding sites in order to facilitate estimation of dispersal. This set an additional challenge: the database should allow efficient synchronisation among data from several local data managers who would keep the responsibility to code the resightings of the birds they banded. In this paper, we present the multi-site database we implemented and discuss its uploading to the internet.

Methods

A database system, called SIAM (for Suivi Individuel d'Animaux Marqués in French), has been developed in Microsoft® Access so that it can run on most local computers. The user interfaces are available in French, Italian, Spanish and English (other languages could easily be added).

A module allowing the synchronisation of new, modified or deleted data among the different databases has been implemented. This synchronisation is coordinated by a database manager leader. Approximately once per month, the database managers send the new data managed since the last synchronisation to the leader. Then the leader checks for possible duplicates of observers or localities possibly entered by the different managers during the period. He then generates a final file which is sent back to the others. The update of their own database is then made with a single click.

There are possibilities to enter the ringing and re-sighting data manually or by importing excel files. A tool is also included to extract raw data into excel or text format according to all the possible ringing and/or re-sighting criterions.

The accompanying letters, the bird life histories and dispersal graphics are produced in the observer's language (the same 4 languages plus Turkish added in 2003) and can be automatically output in pdf format or on paper. SIAM can also generate on demand single individual dynamic maps using MapInfo or static maps as images for several individuals.

Finally, SIAM contains a module which permits to manage the Flamingo supporting scheme with automatic outputs when new observations of a supported bird are registered. More recently we have developed a bridge between SIAM and the Flamingo Atlas web site (www.flamingoatlas.org). It allows the supporter to immediately view on a dynamic map, the travels made by "its" birds.

Result and discussion

At the end of 2001, the new database was presented at Estacion Biologica de Doñana and Fuente de Piedra to gather remarks and adjust the development to the demand of database managers. During the 2nd Greater Flamingo workshop in the Camargue in March 2002, the Spanish and Italian database managers agreed to use this tool henceforth. Spanish and Italian data were then transmitted to La Tour du Valat, where they were formatted and pooled with the French ones. The common database was completed in April 2002 and then sent to Italy and Spain where it has been used immediately.

Progressively, after the new ringing operations initiated in Turkey in 2003, in the Ebro Delta in 2004 and in Algeria in 2006, the new data were integrated into this common database. To date, it contains nearly 45,000 different ringed birds and more than 520,000 resightings.

During the 4th Greater Flamingo workshop we have presented what could become this database by showing the first functionalities of the web ring resighting database of the Audouin's Gulls (www.audouinii.org). This project developed by La Tour du Valat for the Ebro Delta Natural

Park should be finished by 2009. It will allow observers to enter their resightings directly on a website. Location of the resighting will be possible either by using an interactive map, by choosing a locality from a list or by entering GPS coordinates. All functionalities of SIAM, will be included like the exportation of raw data, reserved to the banding project leaders.

When the data are validated by the database managers of each project, the band readers will be able to see the life histories of the birds they observed immediately on the site. An important plus of this new database will be that these life histories will remain available to the observers so that they will be able to track the consecutive observations of a bird they have already observed.

Such a database will present the advantage of reducing the time dedicated to data treatments and to the observer replies, which is far from negligible. Furthermore we believe that it can improve the involvement of volunteers in resighting birds.

Which ring colour looks best: results of the Antequera 'ophtalmic' tests

Nicola Baccetti and Federico Morelli

INFS, Ozzano Emilia BO, Italy. E-mail: nicola.baccetti@infs.it

Abstract
Accurate reading of ring codes is a critical assumption of capture-mark-resighting studies. However, the effects of the different ring characteristics on reading accuracy in the field have not received the attention they deserve. Here we present the results of a very preliminary field test on the performance of a panel of flamingo experts in correctly recording varied sets of colour rings placed at increasing distances on the mudflats of the Fuente de Piedra lagoon. Mistakes occurred most often on dark rings, yellow ones performing best.

Introduction
The correct recording of individual codes that are engraved on colour-rings is of crucial importance in the study of flamingos and marked birds in general. 'Un-recording' colour-marked birds, because of the loss of their marks is frequently acknowledged as a source of bias in studies of bird demography (e.g. Pistorius *et al*. 2007). Mark loss, however, is the very final stage of a process of mark ageing, during which fading and partial breaking are likely to increasingly cause wrong records that seem even more dangerous, as each incorrect record affects two individuals, instead of only one (i.e. one bird that is locally present, whose code is missed, and one that is probably absent, whose code is recorded by mistake).

Plastic quality, strictly related to mark durability, is one of the causes of possible misidentification as a colour ring ages. A number of other variables, however, affect the recording performance even when a ring is new (*e.g*. colour, size and type of code, and many more subtle differences). The effects of ring characteristics on reading accuracy in the field have not received the attention they deserve (see Mitchell and Trinder 2008, and references therein). When starting a new colour ringing project, the ring characteristics are usually selected in terms of common sense, what might well work properly until ringers are few and available combinations many. 'Project overcrowding' of some species (see www.cr-birding.be) or very long-running projects may now strongly constrain the choice and lead to sub-optimal solutions.

The gathering of many experienced 'flamingo-readers' at this workshop in Antequera, Spain was an opportunity to attempt a preliminary field test on their performances in correctly recording varied sets of colour rings at increasing distances on the mudflats of Fuente de Piedra lagoon.

(Human) material and methods
The rings used were the usual size for Greater Flamingos Phoenicopterus roseus (55 mm long with 19 mm inner diameter). They had been purposely produced by ProTouch (Canada) in five different colours with 4-letter codes engraved three times (black codes on white and yellow rings, white codes on blue, green and black rings). The same 15 letters (A B C D F H J K L N P S T V Z) that are used In Italy on wild Greater Flamingos *Phoenicopterus roseus* were randomly present in the codes, each letter being c. 19 mm high and engraved by a 3 mm point. The red colour was not tested, as it was judged to offer not enough contrast with adult flamingos' legs.

Experimental design
Five sticks holding 10 rings (two each of the five colours) were fixed in the solid mud at 50 m intervals, 200 m to 400 m from the observers' position. Only 14 participants could be tested, due to failing light conditions, and not all of them had time to check all sticks. Each observer dictated the colour and code combinations to another person who recorded them on a standard form. Our aim was to test only: i) the accuracy of colour identification and ii) the accuracy of code reading by ring colour. On checking the forms, cases of wrongly identified colours were considered as individual mistakes for the first test, while partial readings and wrong readings (e.g. containing at least one incorrect letter) were both counted as individual mistakes and summed up according to the respective ring colour (second test).

Results

Identification of colours

Most ring colours were correctly identified (Table 1). Very few mistakes were recorded in the case of green, white, black and yellow, while several blue rings were noted as black (but not the reverse).

Table 1. Number of times a given ring was said to be of a given a colour depending on its real colour

	Number of detection as				
Real colour	**green**	**blue**	**white**	**black**	**yellow**
green	102	1	0	1	0
blue	1	92	0	1	0
white	1	0	114	0	2
black	1	21	0	115	0
yellow	0	0	0	0	115

Accuracy of code reading according to ring colour

Table 2 shows first, the percentage of codes that were read correctly (for each colour), and then the sample size (how many rings of each colours were examined by the participants). Mistakes occurred most often on black rings, yellow ones performing best.

Table 2. Percentage of correct reading of ring code by ring colour

Colour	% correct	N
Yellow	91.1	123
White	89.3	121
Green	75.4	129
Blue	75.2	126
Black	69.8	129

Discussion

No statistical analysis was done of these results, because the sample size was small and the test itself very preliminary. Nevertheless, some useful indications are apparent and usually confirm Mitchell and Trinder's (2008) findings, with a few differences: blue being correctly identified as often as the other colours in their case, but being at the same time the colour that accounted for most misread codes, instead of black. The reason for these differences might be either in the shade/brightness of each ring colour used in the two experiments, or to fading light conditions during the Antequera test, or in ambiguous notations on some field sheets (BL abbreviation used for black or blue), all these being possible sources of variability that were not controlled.

There are many other aspects that could be analysed in this way (*e.g.* the effects of distance, and the legibility of the 15 letters). We plan to organize a similar test on the Italian observers' network, taking full advantage from the Antequera trial.

Acknowledgments

We thank the observers who accepted being checked, and the respective secretaries. Thanks to Manolo Réndon and Araceli Garrido for fitting this operation into the social excursion's tight schedule, and to Juan Rubio for very effectively placing the ring sets on the mudflat.

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WORKSHOP COMMUNIQUE

Proposed soda ash development at Lake Natron, Tanzania, threatens the Lesser Flamingo

The Mediterranean and West African Flamingo Network at its fourth international meeting at Antequera (Malaga) Spain on 5-6 November 2007, calls upon the Tanzania government and TATA Chemicals to reconsider the proposed development of the soda ash extraction facility at Lake Natron, Tanzania, given the potential negative inpacts on the Lesser Flamingo.

Anthus snc., Italia
Association des Amis des Oiseaux, Túnez
Consejería de Medio Ambiente, Junta de Andalucía, España
Estación Biológica de Doñana, CSIC, España
Instituto Nazionale per la Fauna Selvática, Italia
Laboratoire de Recherche des Zones Humides, Université d'Annaba, Argelia
Parc National de Banc D'Arguin, Mauritania
Parc Natural Delta de l'Ebre, España
Parco Naturale Regionale Molentargius Saline, Italia
Station Biologique La Tour du Valat, Francia

CONCLUSION

This IVth Workshop on the Greater Flamingo in the Mediterranean region and northwest Africa was an intense and memorable event. Beyond being a meeting of flamingo experts, it has become the regular meeting of the Greater Flamingo Network where is elaborated a shared knowledge on the biology and conservation of this species.

At the origin of the network are scientists regularly participating to ringing operations at each others breeding sites. The strength of the network comes from an original data infrastructure, a common ring-resighting database linking each partner to the others. This database is to be completed soon by an additional layer, a common monitoring scheme for flamingo counts: the flamingo atlas website. The additional value of this collaborative infrastructure was exemplified by the empowerment brought by multi-site studies such as those of Balkiz *et al* or Amat *et al*. They demonstrate the importance of the flyway approach for a proper understanding of the processes driving Greater Flamingo population dynamics.

Despite these promising results, the point was raised that further standardization of data collection could facilitate such meta-analyses. The next workshop should thus reserve a period of time to reach consensual "monitoring guidelines" that would be endorsed by all network members.

Finally, while the network for developing scientific studies on the Greater Flamingos is now working efficiently, breeding sites remain managed locally. Further effort should be put in developing a network of site managers where to discuss and implement large scale management and conservation plans for the Greater flamingo. In particular, salt pans abandonment in the North of the Mediterranean region and climate warming in the South are major forthcoming challenges which will have to be addressed collectively if we want to maintain this population at its current level in the future.

Arnaud Béchet, Eastern Hemisphere Chair

El IVème Taller sobre el Flamenco Común en el Mediterráneo y en el noroeste de África fue un intenso y memorable evento. Más allá de ser una reunión de expertos en flamencos, es ahora la reunión de referencia de la red de estudio del Flamenco común. Por lo tanto, es el lugar donde se desarrolla un intercambio de conocimientos sobre la biología y la conservación de esta especie.

En el origen de la red están los científicos que participan regularmente en operaciones de anillamiento en cada uno de los lugares de cría. La fuerza de la red proviene de una infraestructura de datos original, una base de datos común de anillamiento-lecturas que vincula cada uno de los socios. Esta base de datos se completará en breve por una capa adicional, un sistema común de seguimiento de flamenco, que será gestionada a través de la página web flamingoatlas. El valor adicional de esta infraestructura de colaboración esta aquí demostrado por el refuerzo de por los estudios multi-sitio, tales como los de Balkiz *et al.* o Amat *et al.* Ellos demuestran la importancia de tomar en cuenta el área de repartición del flamenco para una correcta comprensión de los procesos que gobiernan la dinámica de su población.

A pesar de estos resultados prometedores, se ha demostrado que una mayor normalización de la recopilación de datos (Rendón *et al*.) podría facilitar este tipo de meta-análisis. El próximo taller de flamencos debería reservar un período de tiempo para elaborar "monitoring guidelines", que serían aprobados por los miembros de la red.

Por último, aunque la red para el desarrollo de estudios científicos sobre el Flamenco común está trabajando de manera eficiente, los sitios de reproducción siguen siendo gestionados a nivel local. Se debe poner un mayor esfuerzo en el desarrollo de una red de administradores de los sitios donde se pueda debatir y poner en práctica modelos de gestión y planes de conservación para el Flamenco común. En particular, abandono de salinas en el norte de la región del Mediterráneo y el calentamiento del clima en los países del Sur son los principales futuros desafíos que tendrán que abordarse en su conjunto si queremos mantener esta población en su nivel actual en el futuro.

Arnaud Béchet, Eastern Hemisphere Chair

FLAMINGO SPECIALIST GROUP

The Flamingo Specialist Group (FSG) was established in 1978 at La Tour du Valat in France, under the leadership of Dr. Alan Johnson, who coordinated the group until 2004. Currently, the group is coordinated from the Wildfowl & Wetlands Trust at Slimbridge, UK, as part of the IUCN-SSC/Wetlands International Waterbird Network.

The FSG is a global network of flamingo specialists (both scientists and non-scientists) concerned with the study, monitoring, management and conservation of the world's six flamingo species populations. Its role is to actively promote flamingo research, conservation and education worldwide by encouraging information exchange and cooperation among these specialists, and with other relevant organisations, particularly the IUCN Species Survival Commission (SSC), Wetlands International, the Ramsar Convention on Wetlands, the Convention on Conservation of Migratory Species (CMS), the African-Eurasian Migratory Waterbird Agreement (AEWA), and BirdLife International. The group is coordinated from the Wildfowl & Wetlands Trust, Slimbridge, UK, as part of the IUCN-SSC/Wetlands International Waterbird Network.

FSG members include experts in both *in-situ* (wild) and *ex-situ* (captive) flamingo conservation and education, as well as in fields ranging from research surveys to breeding biology, infectious diseases, toxicology, movement tracking and data management. There are currently 270 members representing 185 organisations in 56 countries around the world, from India to Chile, and from France to South Africa. Further information about the FSG, its membership, the membership list serve, or this bulletin can be obtained from Brooks Childress at the address below.

Chair
Dr. Brooks Childress
Wildfowl & Wetlands Trust
Slimbridge
Glos. GL2 7BT, UK
Tel: +44 (0)1453 860437
Fax: +44 (0)1453 860437
Brooks.Childress@wwt.org.uk

Western Hemisphere Chair
Dr. Felicity Arengo
American Museum of Natural History
Central Park West at 79th Street
New York, NY 10024 USA
Tel: +1 212 313-7076
Fax: +1 212 769-5292
arengo@amnh.org

Eastern Hemisphere Chair
Dr. Arnaud Béchet
La Tour du Valat
Le Sambuc
13200 Arles, France
Tel : +33 (0) 4 90 97 20 13
Fax : +33 (0) 4 90 97 20 19
bechet@tourduvalat.org

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